Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage: www.akademiabaru.com/ard.html
ISSN: 2289-7984

Substrate Integrated Waveguide Coupler

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ARTICLE INFO

Article history:
Received 5 June 2017
Received in revised form 10 July 2017
Accepted 4 December 2017
Available online 16 March 2018

Keywords:
Directional coupler, SIW, coupling coefficient

ABSTRACT

A Substrate Integrated Waveguide (SIW) 3dB directional coupler is presented. It is implemented on the glossy material (Rogers R04350), with substrate thickness 1.524 mm, loss tangent of 0.04 and relative permittivity 3.66. Different via profiles are investigated. It conducts coupling coefficient of 3 dB with some losses contributed from the structure. The via profile conducts the change in the bandwidth of the coupler which can help in tuning the coupler bandwidth.

1. Introduction

Substrate Integrated Waveguide; SIW was originally invented in 1994 by the Japanese scientist Shigeki [1]. Unlike hollow WGs with bulky size and higher fabrication cost, SIW can be fabricated on printed circuits with significantly reduced cost and size [2-6]. It consists of a top and bottom conductive layer provided on each side a substrate all along. These top and bottom metallization layers are connected by a row of via holes. SIW typically operate in the TE10 mode since the substrate height is much smaller than the strip width. Unlike regular WGs, SIWs are dielectric filled WGs.

The SIW has been widely developed for integrated microwave and millimeter-wave components and antennas. Concerning these aspects, the SIW couplers have many publications [7-15] in addition to its small size and low cost. It shows good performances with broad operation bandwidth, low insertion loss, low return loss and high isolation. This article presents a 3dB SIW directional coupler with different via profiles which can help in tuning the coupler bandwidth.

2. Double Waveguide Design

The double SIW is investigated firstly for the sake of studying the losses due to the structure and higher order modes. The geometrical configuration of the proposed double waveguide is

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shown in Fig. 1. It is designed on 1.524 mm thick Rogers RO4350 substrate with permittivity (εr) 3.66 and tangent loss 0.004. The overall double waveguide size is 53.7 × 29.08 mm². The following condition has been considered $\frac{P}{d} < 2.5$ and $0.05 < \frac{p}{\lambda_c} < 2.5$.

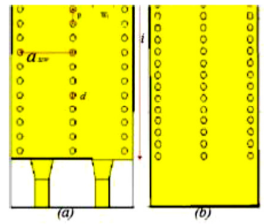

Fig. 1. Double SIW design (a) Front side, (b) back side

The double SIW dimensions are depicted in table 1. The fabricated one is illustrated in Fig. 2.

Table 1
Design dimensions in mm

Dimension	L	L_t	a_{siw}	i	p	d	W_{50}	W_t
Value	6	4.17	12.54	33.38	2.5	1.4	3.33	5.33

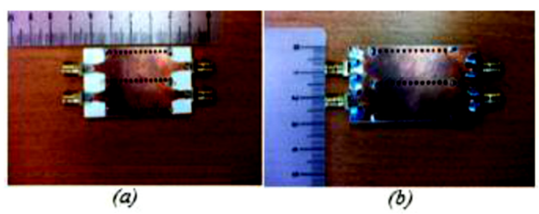

Fig. 2. Fabricated double SIW (a) front side, (b) back side

The simulated scattering parameters of the double SIW implemented on glossy Rogers RO4350 material are shown in Fig. 3, while for the case of the lossless material is depicted in Fig 4.

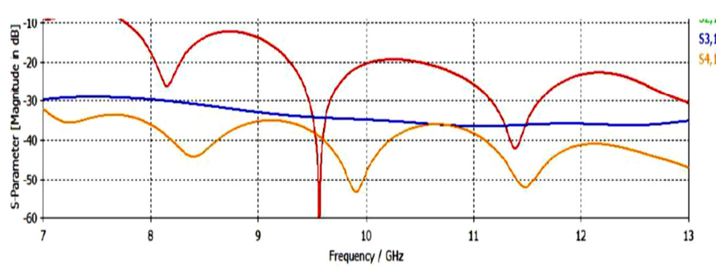

Fig. 3. Scattering parameters of the double SIW with glossy material

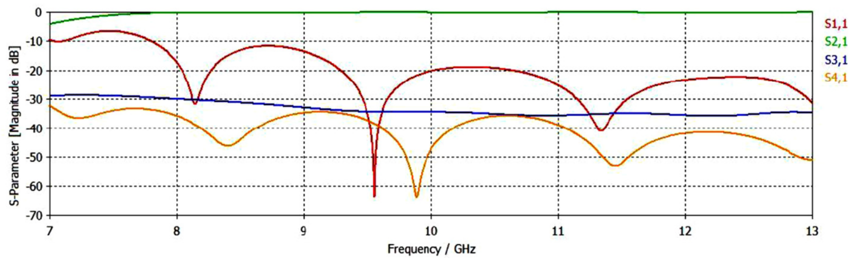

Fig. 4. Scattering parameters of the double SIW with glossless material

From the previous figures one notices that for the case of lossless material, there is a spreading of the signal due to the higher order modes, which is about 0.219dB. On the other hand the glossy material adds losses of 0.42 dB, i.e., there is a total loss for a glossy material of about 0.7dB. The measured scattering parameters are shown in Fig. 5. One notices the good agreement between the measured and simulated results.

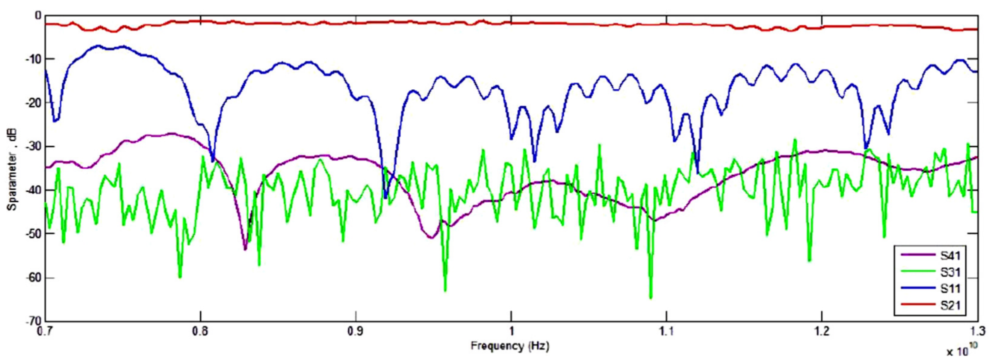

Fig. 5. Scattering parameters of the fabricated double SIW

3. Design of Coupler

The coupler is implemented on the lossy material (Rogers R04350), with substrate thickness 1.524 mm, loss tangent of 0.004 and relative permittivity 3.66. Fig. 6 shows different coupler configurations (the front side only) to assess the 3dB coupling coefficient (S21 or S31). The simulated coupling coefficients (S21) are illustrated in figure 7. The red, orange, blue and green colors are concerning the coupler configurations depicted in figure 6 a, b, c and d respectively. Figure 8 depicts a coupler configuration with via profile that gives a perfect coupling coefficient of 3 dB shown in figure 9, regardless the attenuation due higher order modes and the coupler materials.

More investigations are carried out for the coupler structure to see the effect of via profile on the coupling coefficient and the resonance frequency. Seven profiles are selected, starting from straight line profile at the couplers edges up to the cured via profile shown in Fig. 8. Figs 10-16 presents the scattering parameters for the seven profiles depicted in each figure.

Table 2 illustrates the bandwidth and resonance frequency for each profile. One concludes that the more curved the via profile, the higher bandwidth and resonance frequency.

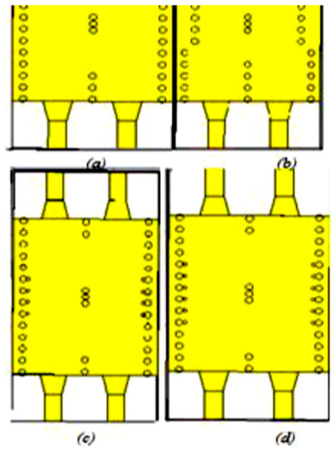

Fig. 6. Different coupler configurations

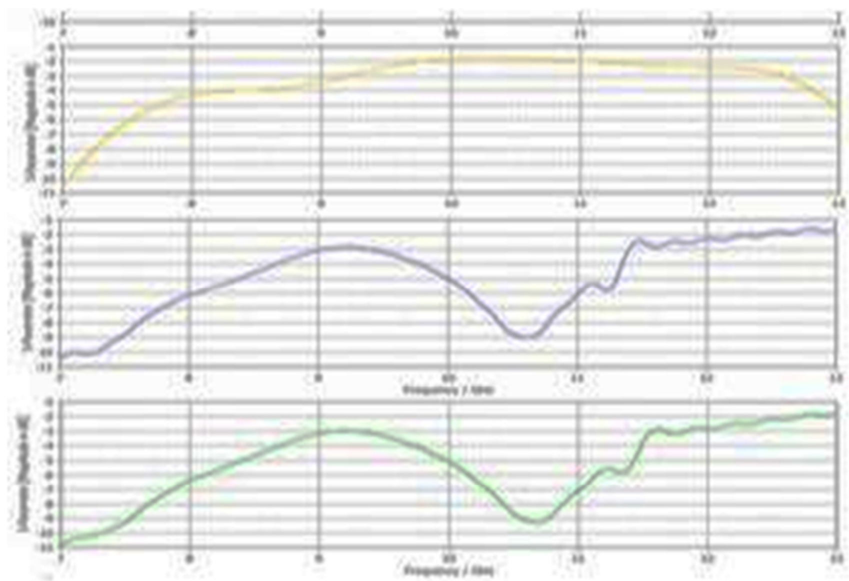

Fig. 7. Simulated coupling coefficients (S_{21}) of different coupler configurations

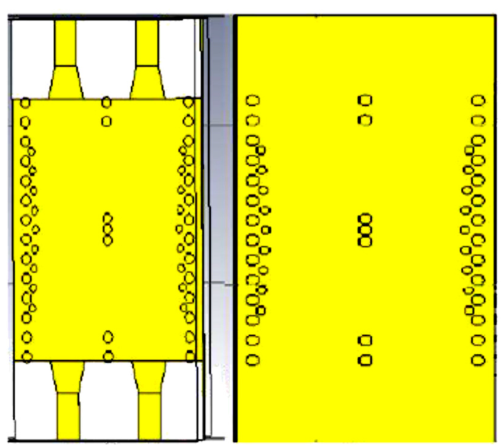

Fig. 8. SIW coupler structure (left) front side (right) back side

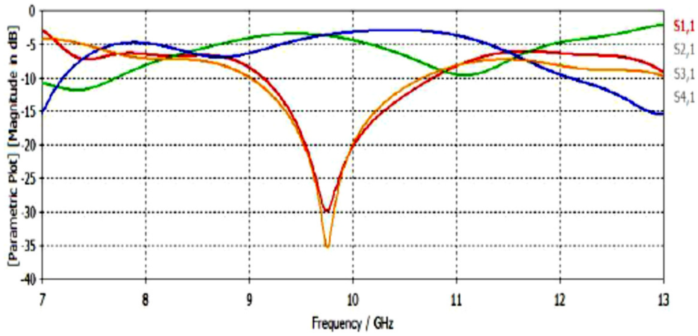

Fig. 9. Simulated scattering parameters of the 3dB coupler

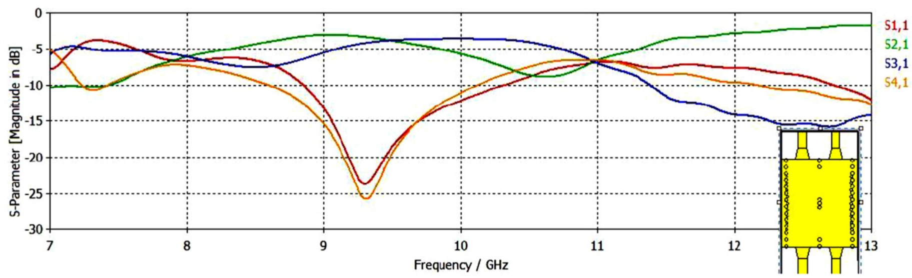

Fig. 10. Scattering parameters of the first profile

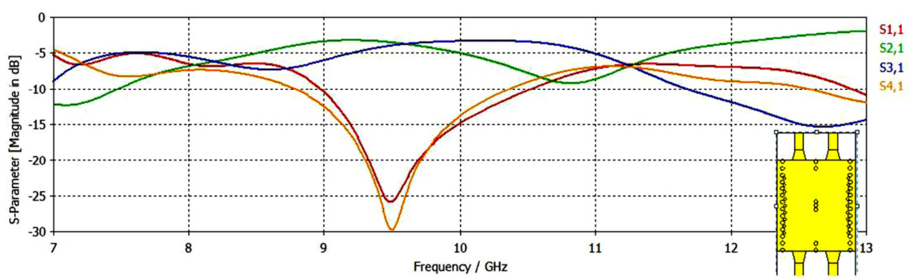

Fig. 11. Scattering parameters of the second profile

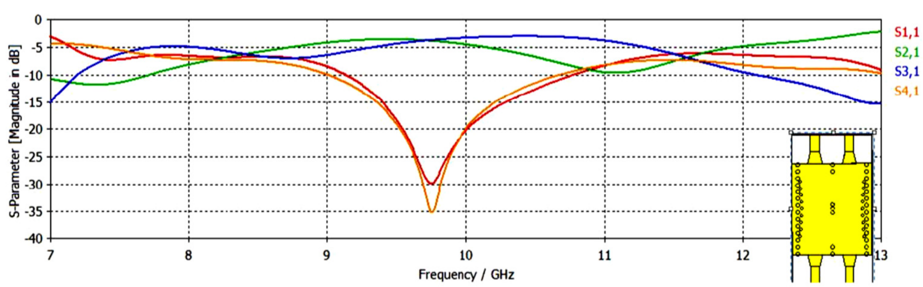

Fig. 12. Scattering parameters of the third profile

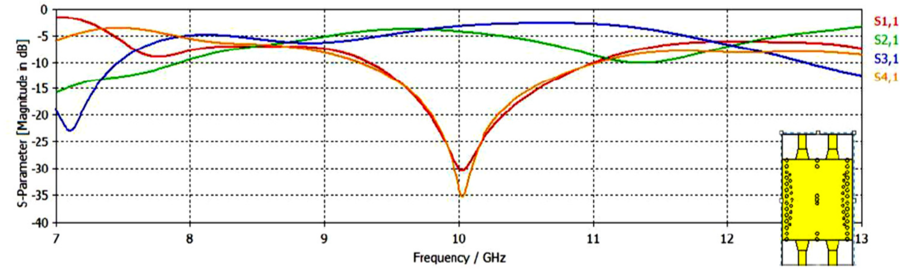

Fig. 13. Scattering parameters of the fourth profile

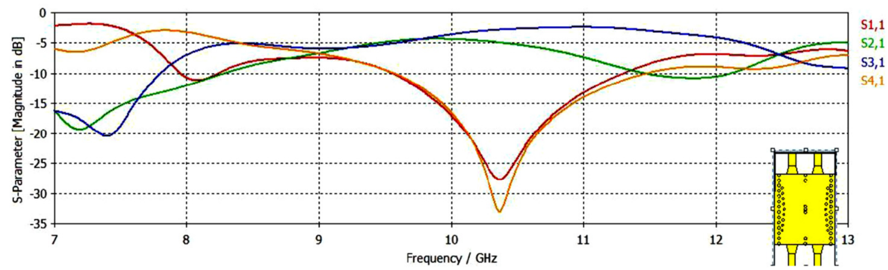

Fig. 14. Scattering parameters of the fifth profile

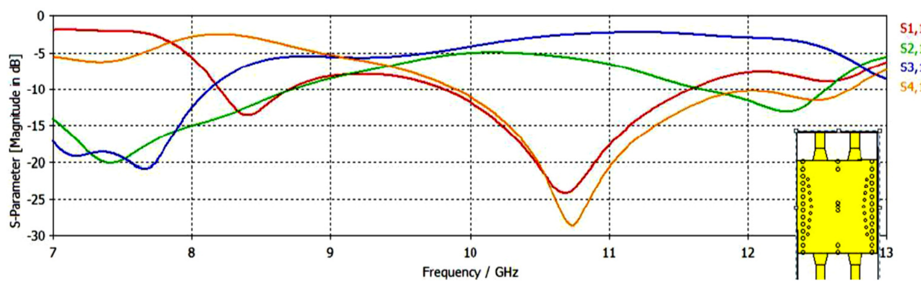

Fig. 15. Scattering parameters of the sixth profile

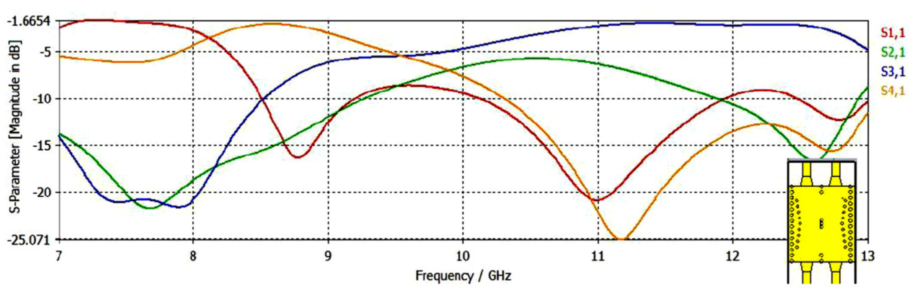

Fig. 16. Scattering parameters of the seventh profile

Table 2
Bandwidth and resonance frequency for different profiles

#	Bandwidth (GHz)	Resonance frequency (GHz)
1	8.85 - 10.34	9.3
2	9 – 10.5	9.49
3	9.13 – 10.77	9.75
4	9.34 – 11	10.03
5	9.55 – 11.3	10.36
6	9.81 – 11.58	10.7
7	10.11 - 11.95	10.99

4. Conclusion

A 3dB directional coupler designed, analyzed and fabricated an SIW with a compact size. The coupler is implemented on Rogers 4350 material with loss tangent 0.004, thickness 1.524 mm and permittivity 3.66.The overall size of the coupler is 53.7 × 29.08 mm^2. Unlike hollow waveguides with bulky size and higher fabrication cost, SIW coupler fabricated on printed circuits with significantly reduced cost and size. The double SIW structure is implemented for confirmation of the perfect matching between the fabricated and simulated results. Seven via profiles are investigated, starting from straight line profile at the couplers edges up to the cured via profile. The more curved the via profile, the higher bandwidth and resonance frequency of the coupler.

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